Michigan GI Conference –Lansing, MI – 10May14

Moving from "LID" to "Green Infrastructure:" Looking beyond Qp Mitigation & Volume Reduction

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My Motivation

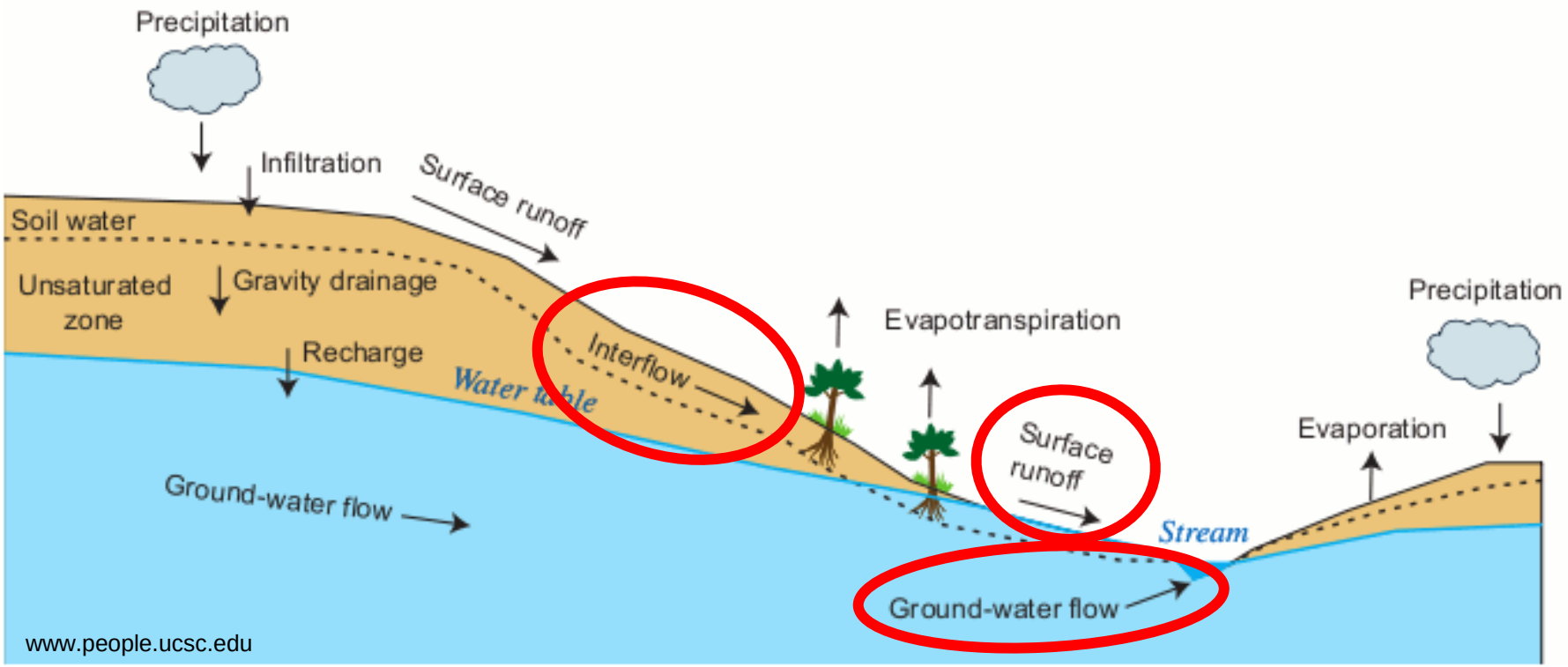
Acknowledgements

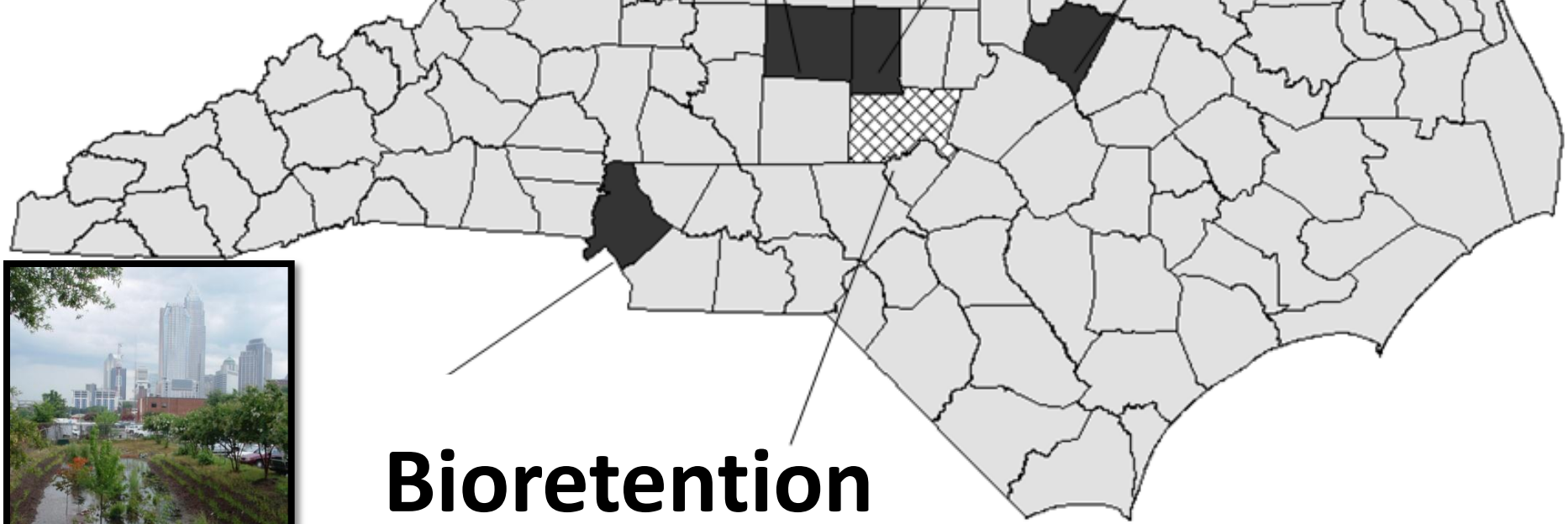
- Dr. Trisha L.C. Moore, former PhD student
  - Research Associate, University of Minnesota
- Ms. Natalie Bouchard, former MS student
  - Project Engineer, Altamonte Environmental

We “know” LID (OK, we don’t)

- Applied on a broad scale, LID can maintain or restore a watershed's hydrologic and ecological functions.
  - USEPA, http://water.epa.gov/polwaste/green/

HYDROLOGIC CYCLE UNDER NATURAL CONDITIONS

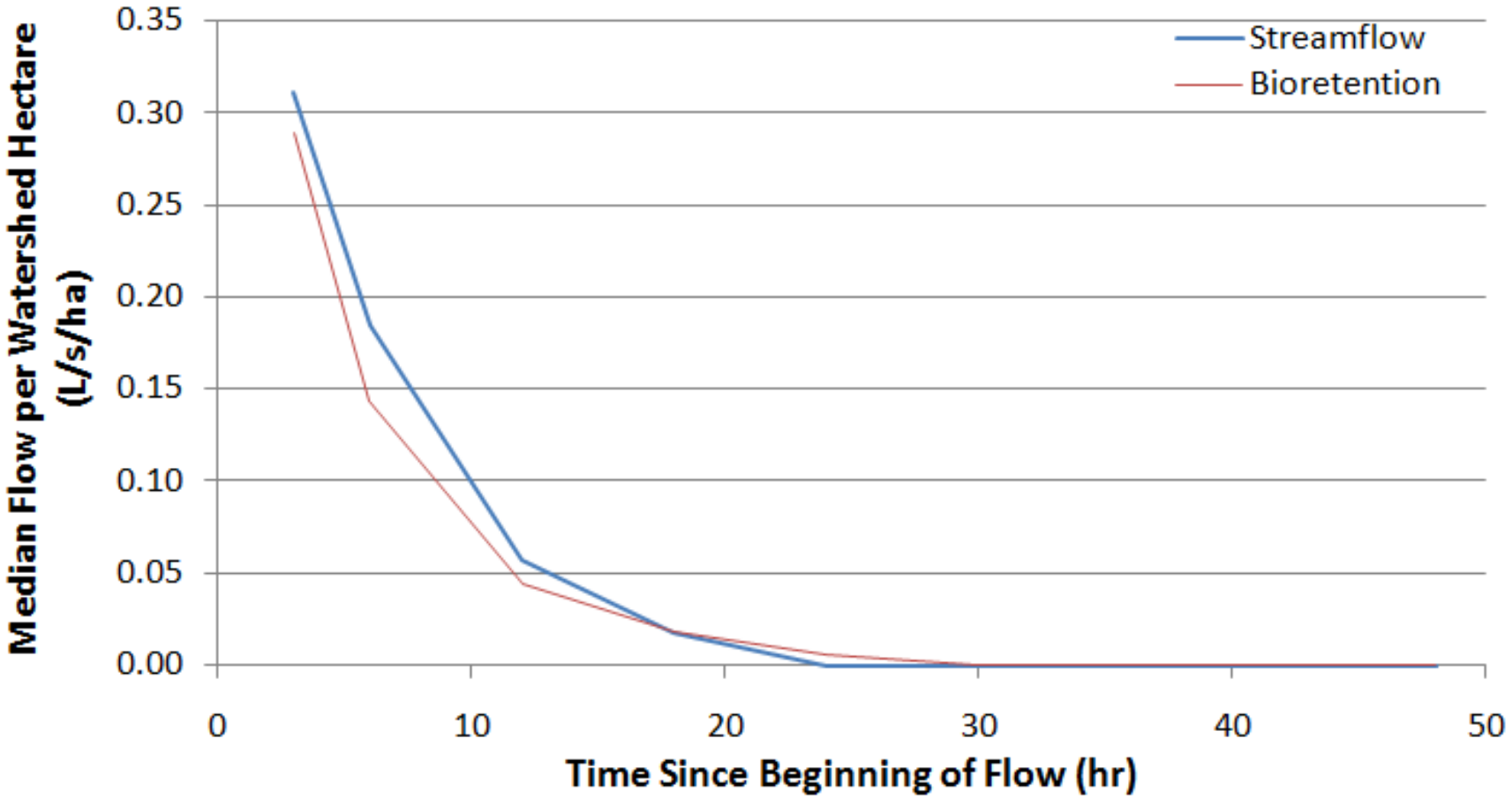




Bioretention Study Sites

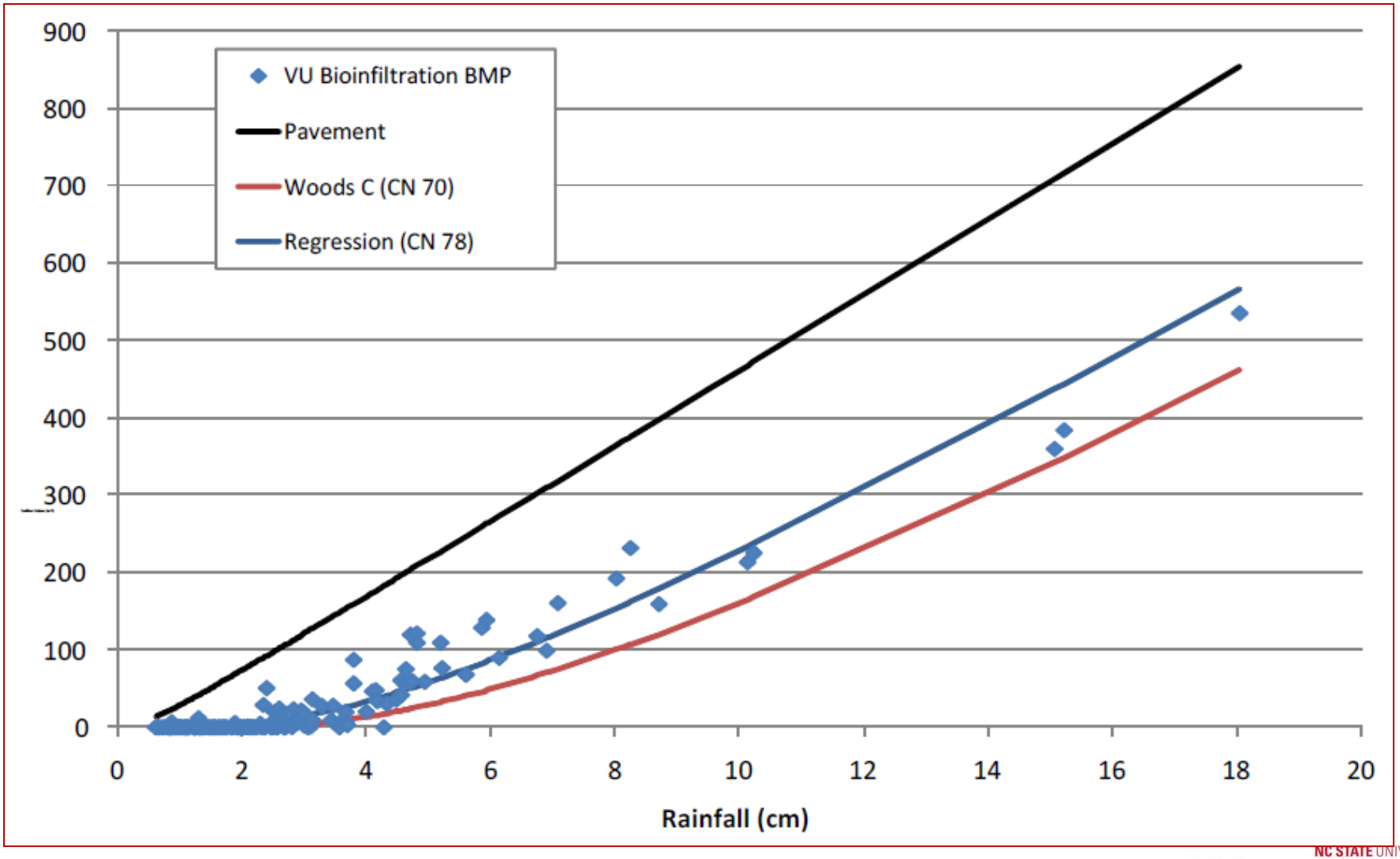
www.bae.ncsu.edu/stormwater

Median Flow Rates per Watershed HA



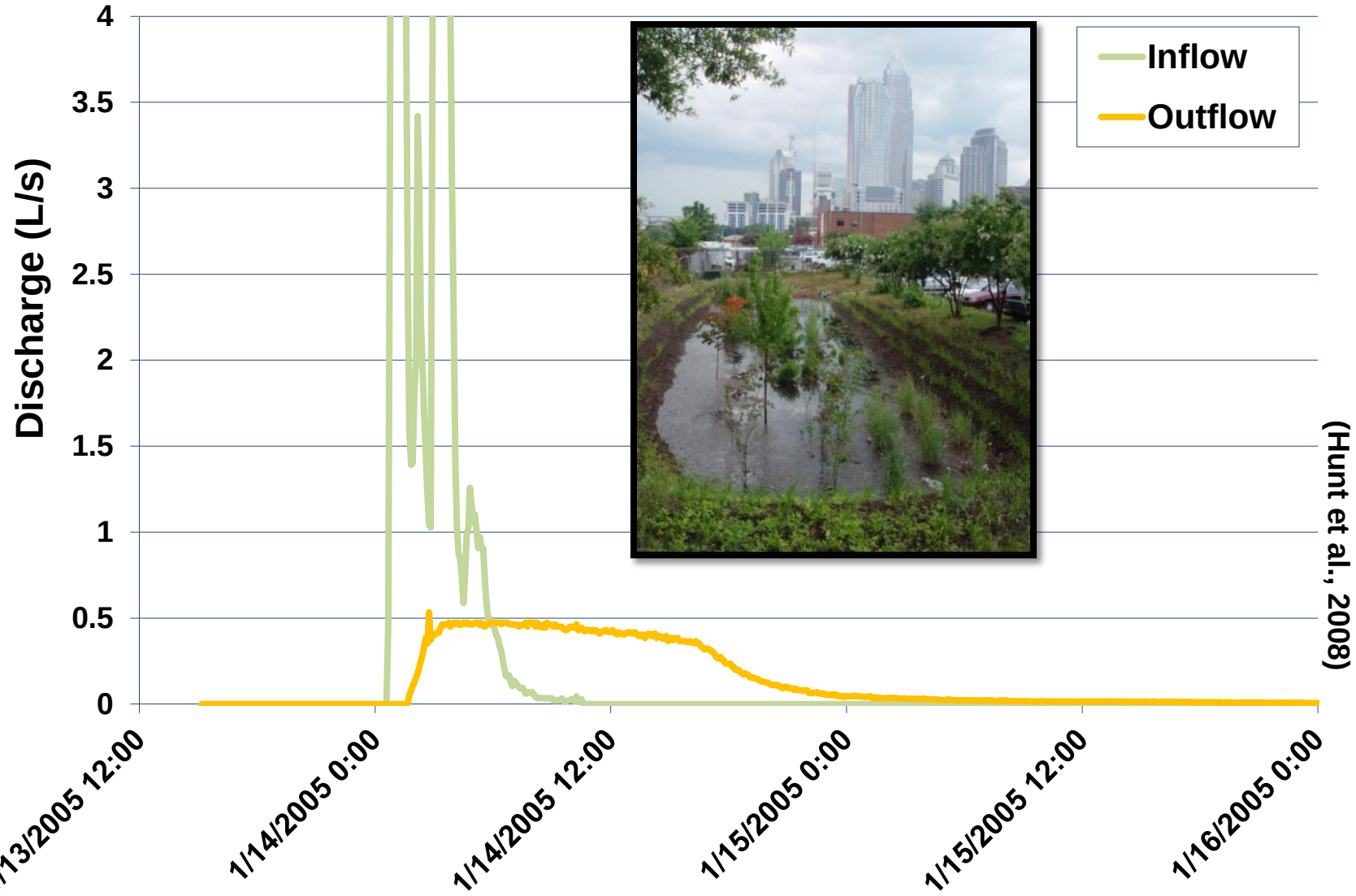
DeBusk et al., JHE, March 2011

LID SCMs – "Bring Back" Hydrology



Davis et al., JHE, May 2012

Peak Flows Can be Mitigated



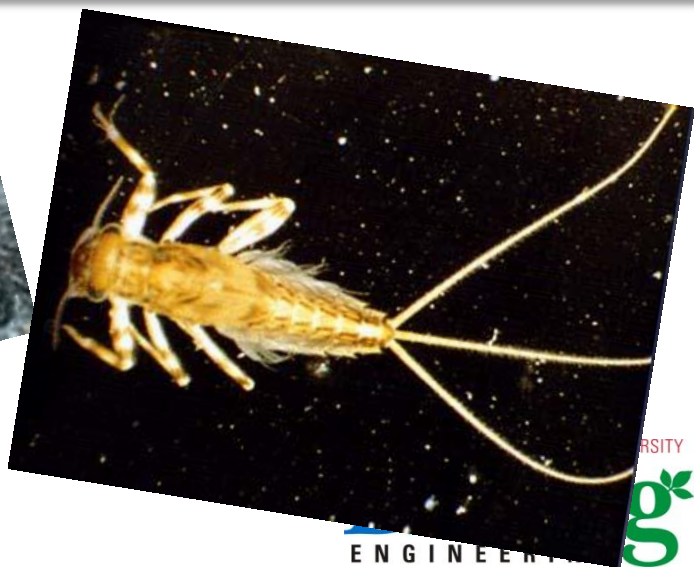
Hunt et al. 2008. JEE. - April

Mass Loads (kg/ha/yr)

	CP		SS	
	In	Out	In	Out
TSS	1190	37	570	38
Chromium	0.09	0.015	0.02	~0.007
Copper	0.26	0.073	0.12	0.045
Lead	0.09	0.013	0.03	~0.005
Zinc	1.0	0.063	0.36	0.017
Chloride	6800	458	320	25
TN	27	7.2	9.6	3.6
Nitrate	12	2.5	3.7	~0.19
TKN	15	4.1	6.0	3.6
TP	3.6	0.72	0.9	0.38
TOC	44	154	43	78

Li & Davis, J. Env. Eng. 2009

Rating	Description of Benthos	Sample Organisms by Scientific Name
Excellent	Very sensitive	Ephemera Guttulata (mayfly), Litobrancha recurvata (mayfly)
Good	Sensitive	Drunella allegheniensis (mayfly), Rhyacophila fuscula (caddisfly
Good-Fair	Semi-tolerant	Amnicola (snail), Elliptio complanata (mussel)
Fair	Tolerant	Cambarus (crayfish), Crangonyx (crustacean)
Poor	Very tolerant	Enchytraeidae (worm), Limnodrilus cervix (worm)



1. http://commons.wikimedia.org/wiki/Image:Water_snail_Rex_1.jpg
2. http://www.adam-hart-davis.org/
3. www.biol.andrews.edu/.../pond_crayfish_index.htm
4. www2.mdbc.gov.au/.../invertebrates/mayfly.htm
5. jimswan.com/111/aquaticinsects.htm

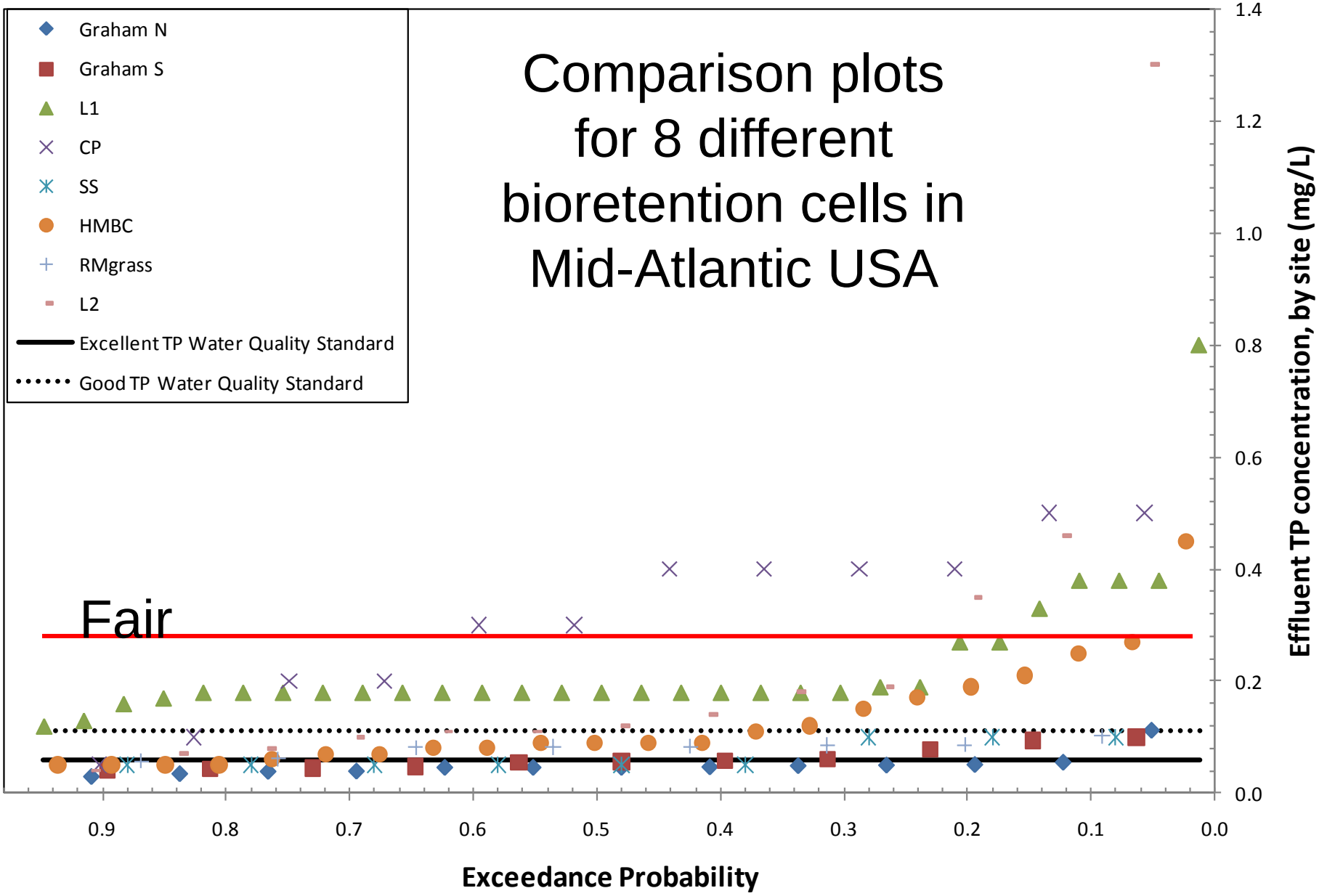
Piedmont

	PIEDMONT			
	Constituent concentration (mg/L)			
Rating	DO	TSS	TN	TP
E	9.25	4.00	0.69	0.06
G	8.80	6.40	0.99	0.11
GF	8.40	5.00	1.17	0.13
F	7.70	7.00	2.16	0.22
P	6.80	5.00	7.59	0.63

McNett et al. JEE. May 2010

Effluent TP concentration Exceedance Probability Plot

McNett et al. 2011

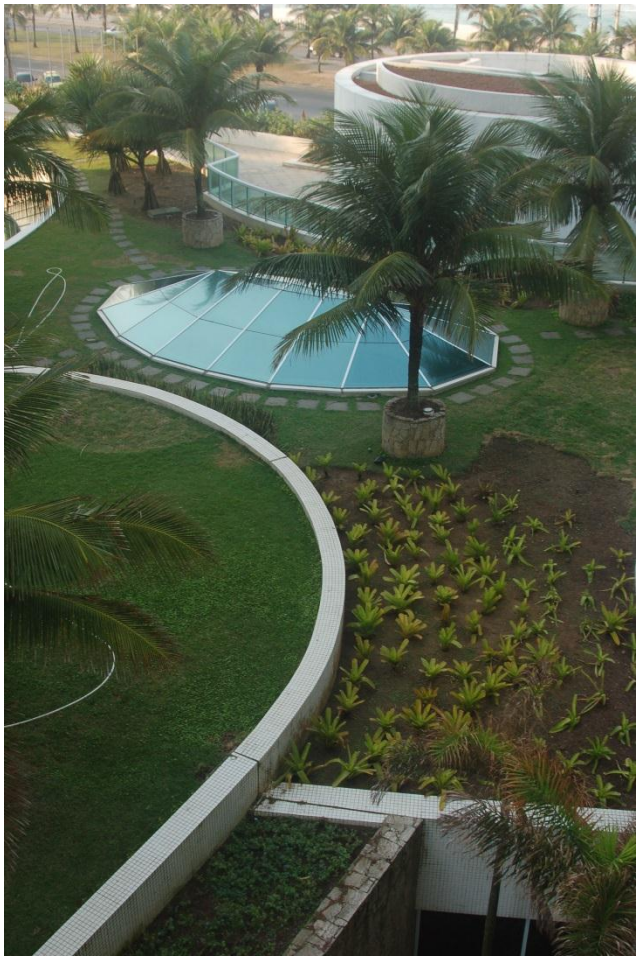


But, what else do we “get?”

Permeable Pavement: You can park on it!

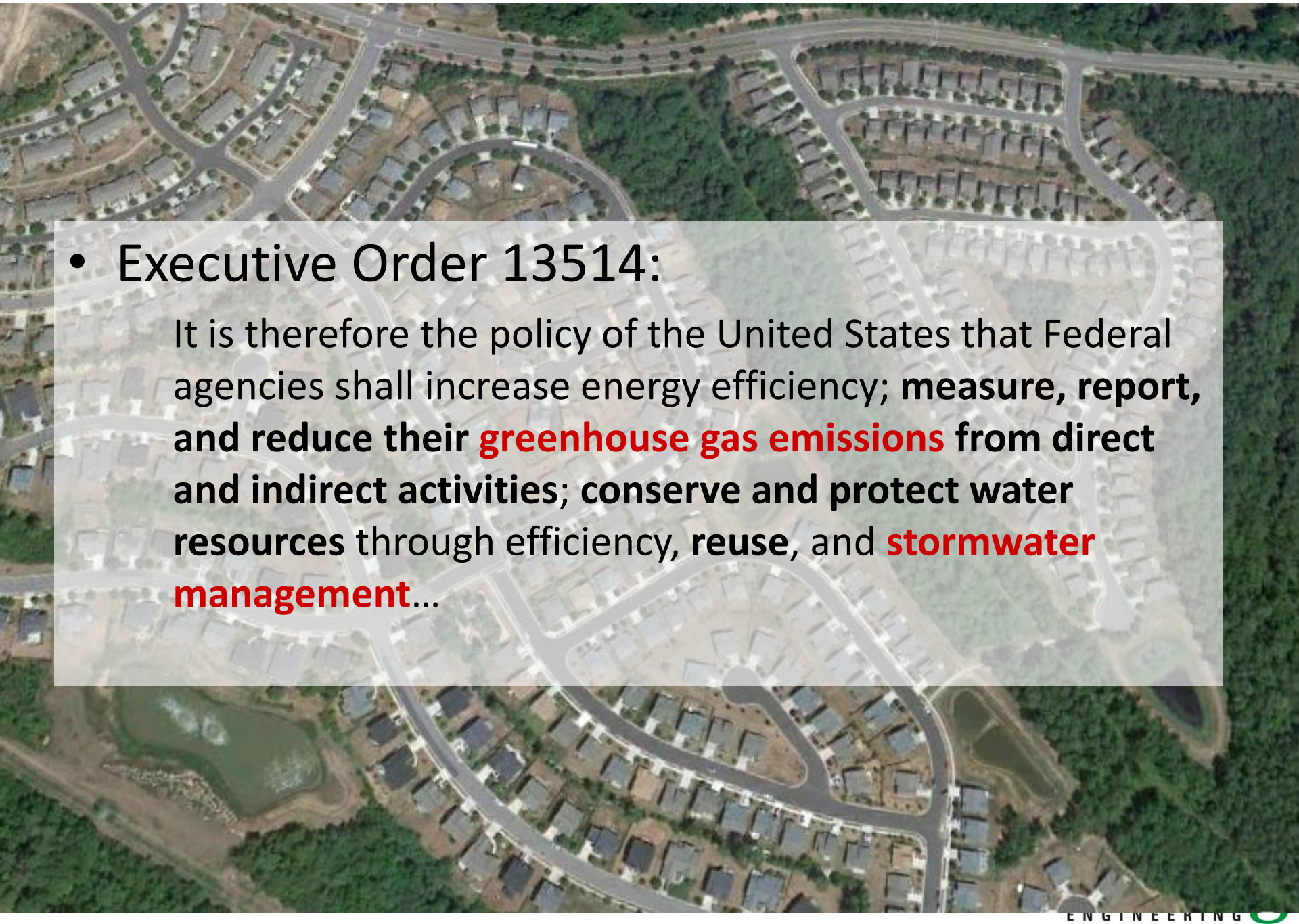
Green Roofs

- Reduction of Heat Island
- Increased Roof Life
- New Living Space
- Increase property value
- They're pretty
- They can save the world



Safety Benefits?

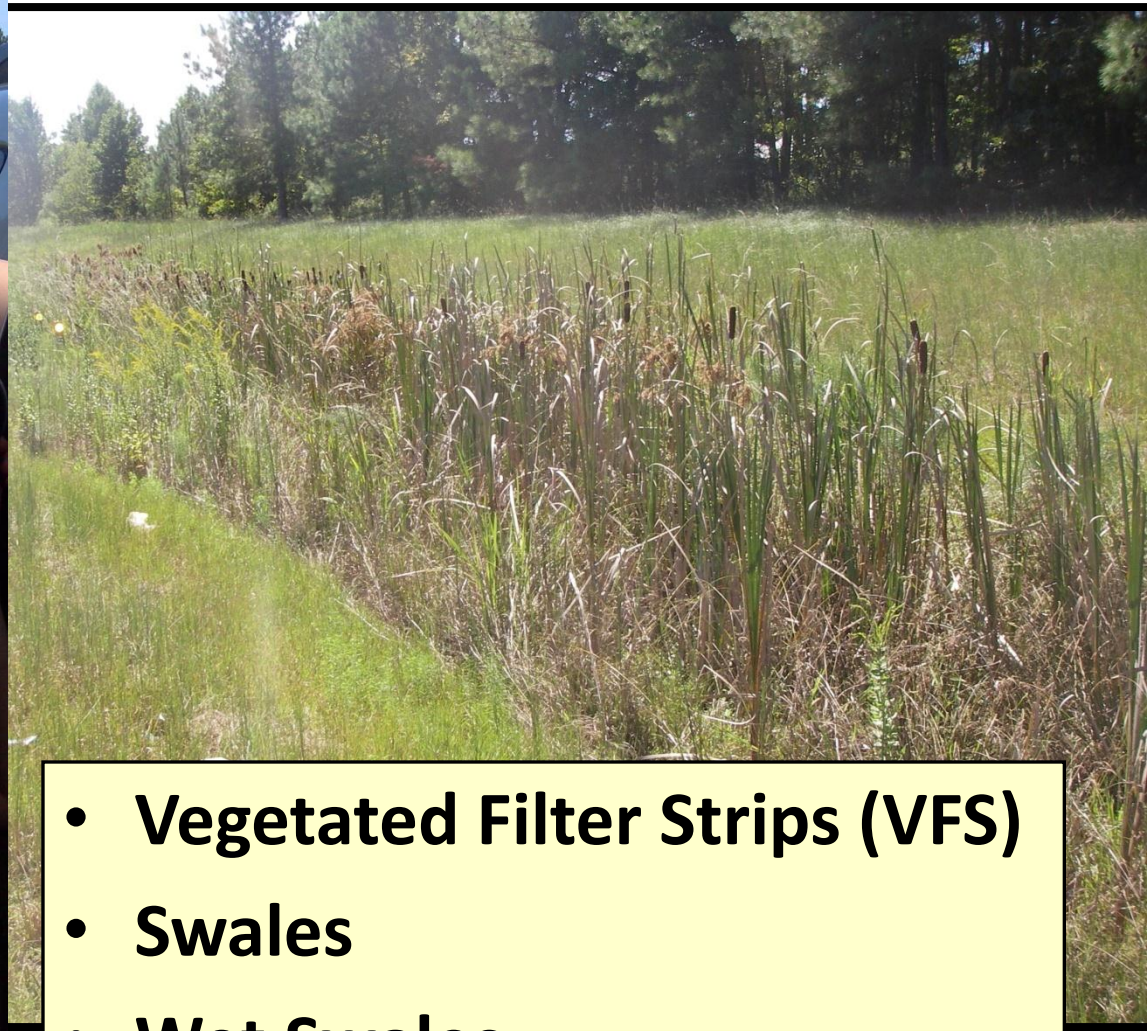
Rainwater Harvesting: Drink it Baby!



- Executive Order 13514:

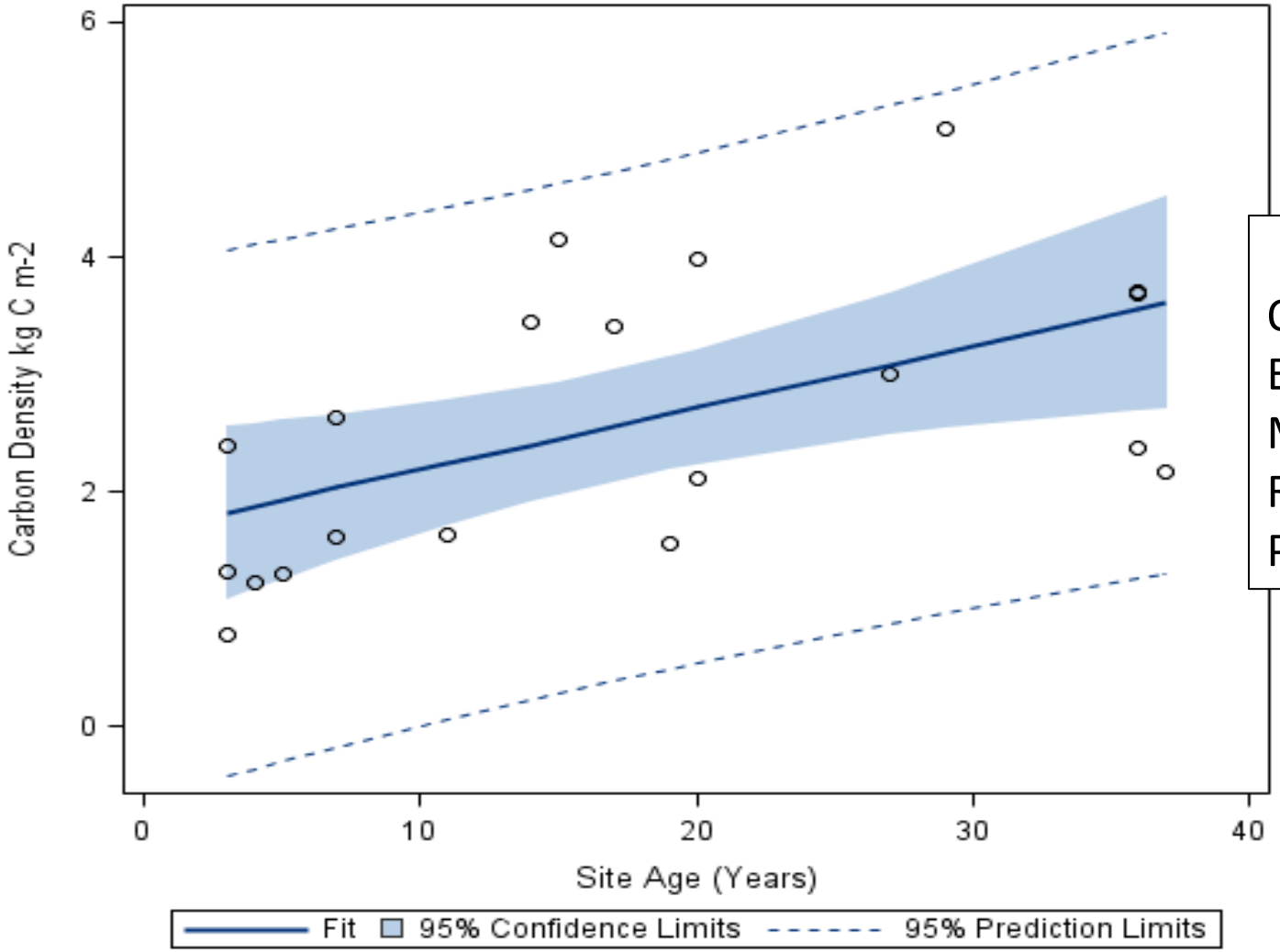
  It is therefore the policy of the United States that Federal agencies shall increase energy efficiency; **measure, report, and reduce their greenhouse gas emissions from direct and indirect activities**; **conserve and protect water resources** through efficiency, **reuse**, and **stormwater management**…

Roadside SCMs



- **Vegetated Filter Strips (VFS)**
- **Swales**
- **Wet Swales**

Results – At what rate do Piedmont VFS/VSs sequester carbon?



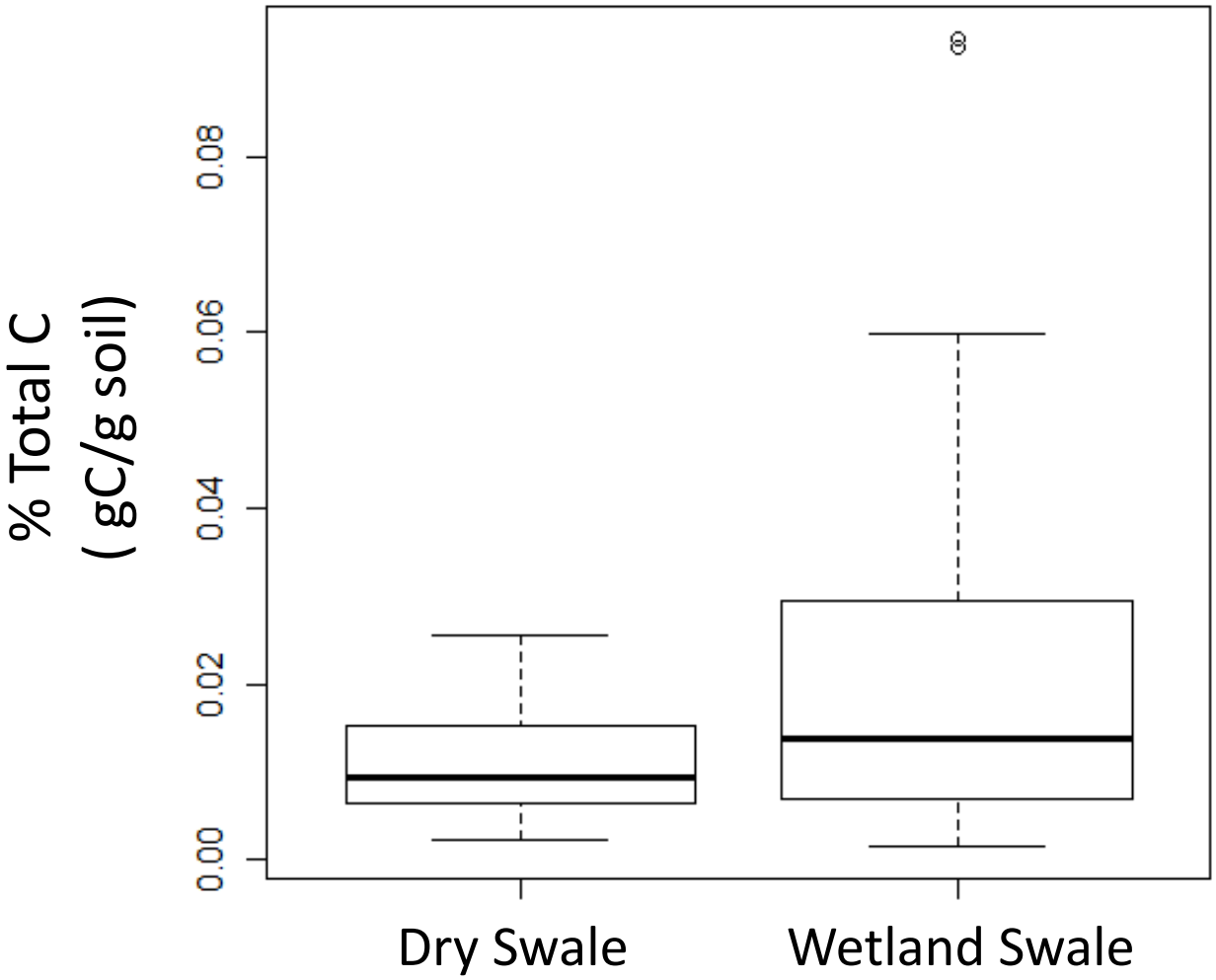
y = 1.66 + 0.053X	
Observations	20
Error Df	18
MSE	1.016
R-Square	0.305
P-value	0.012

Bouchard et al. Ecol Eng. May 2013

Wetland Swale vs. Dry Swale

Results - Does swale type affect % Total C?

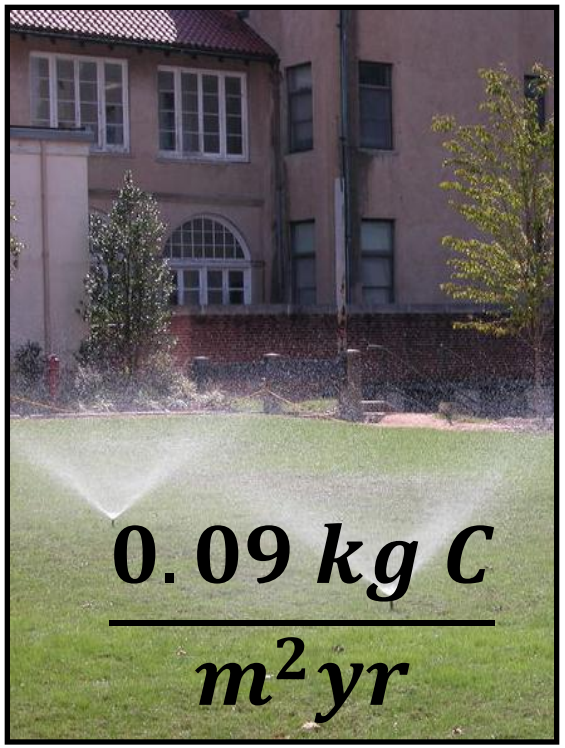
Yes **p=0.0409**



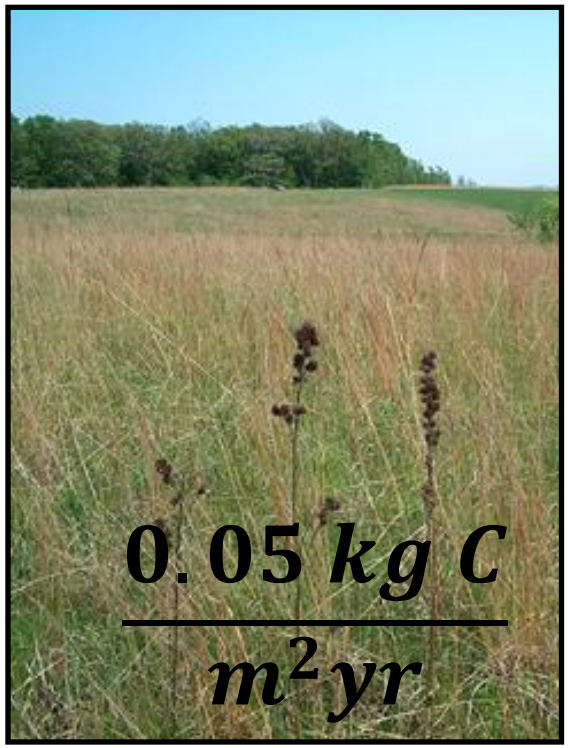
Bouchard et al. Ecol Eng. May 2013

Roadside Data

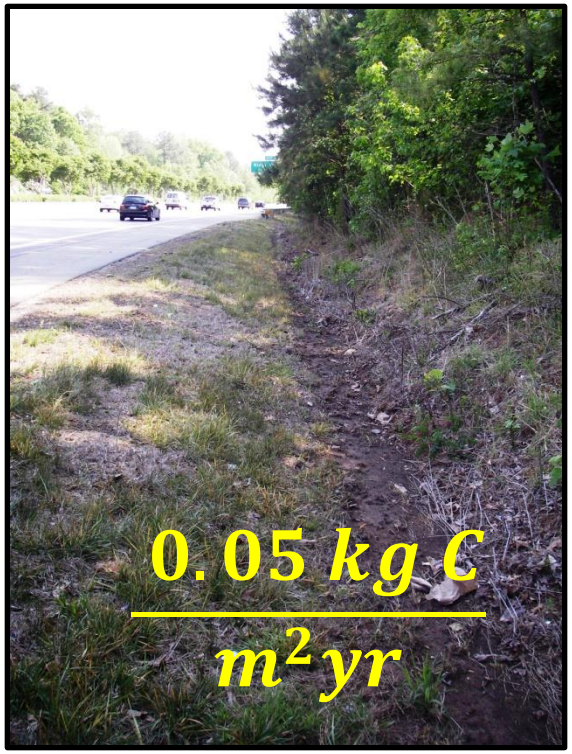
Turfgrass



Native Grassland



Roadside Environment



C values from (Pouyat et al., 2009; Conant, 2001)

And what about Complete Carbon Budgets?

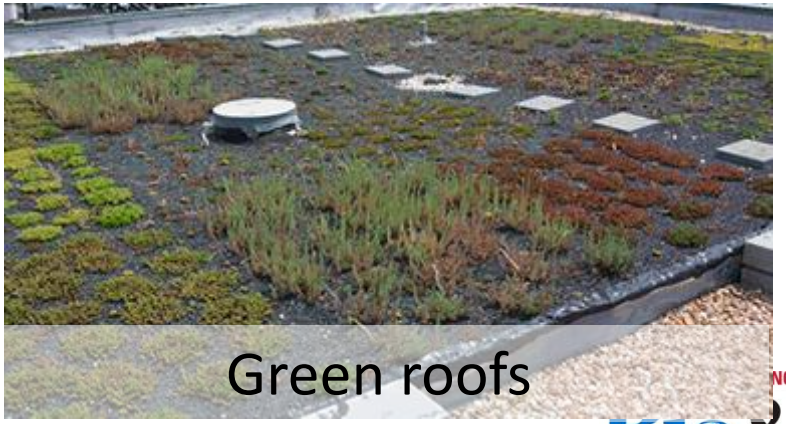
Methods

- SCMs considered:

Level spreader - filter strip

Bioretention

Wetlands



Green roofs

Methods

- SCMs considered:


Sand filters

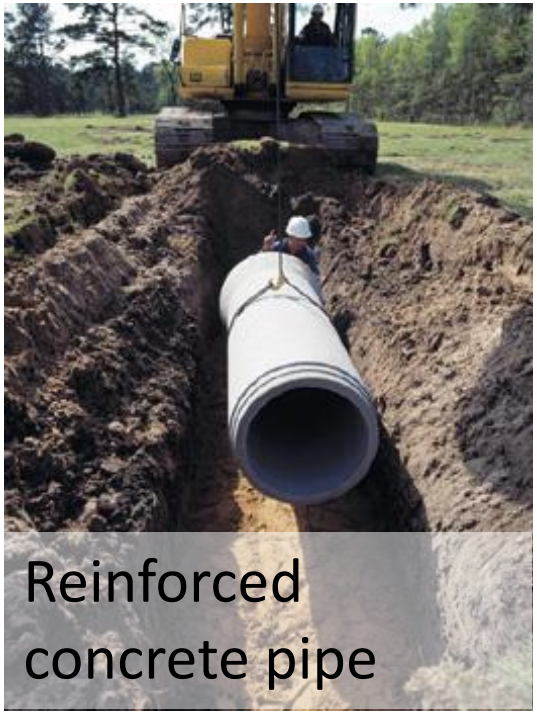

Wet ponds


Permeable pavement


Rainwater harvesting

Methods

- SCMs/ Conveyances considered:

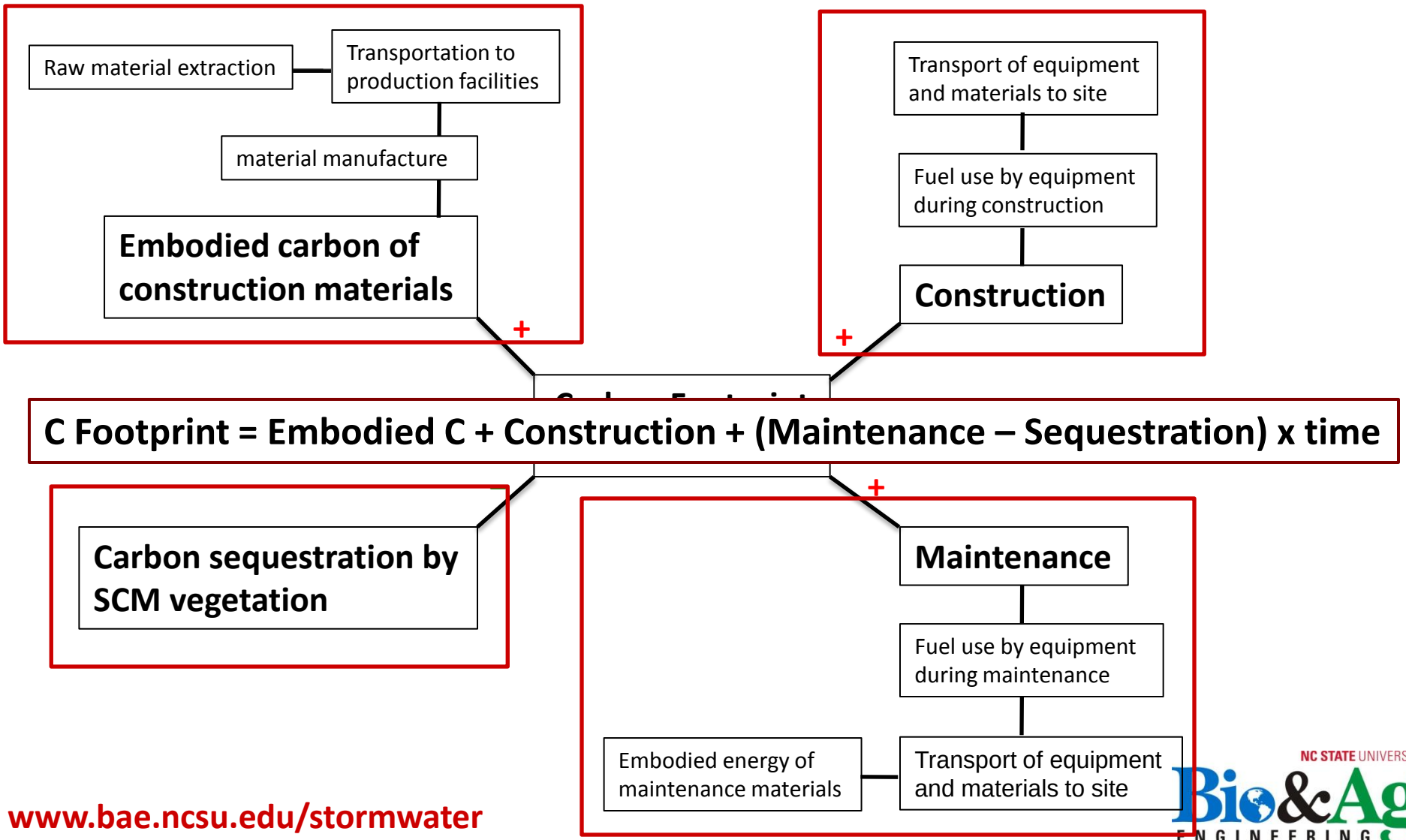


Reinforced concrete pipe

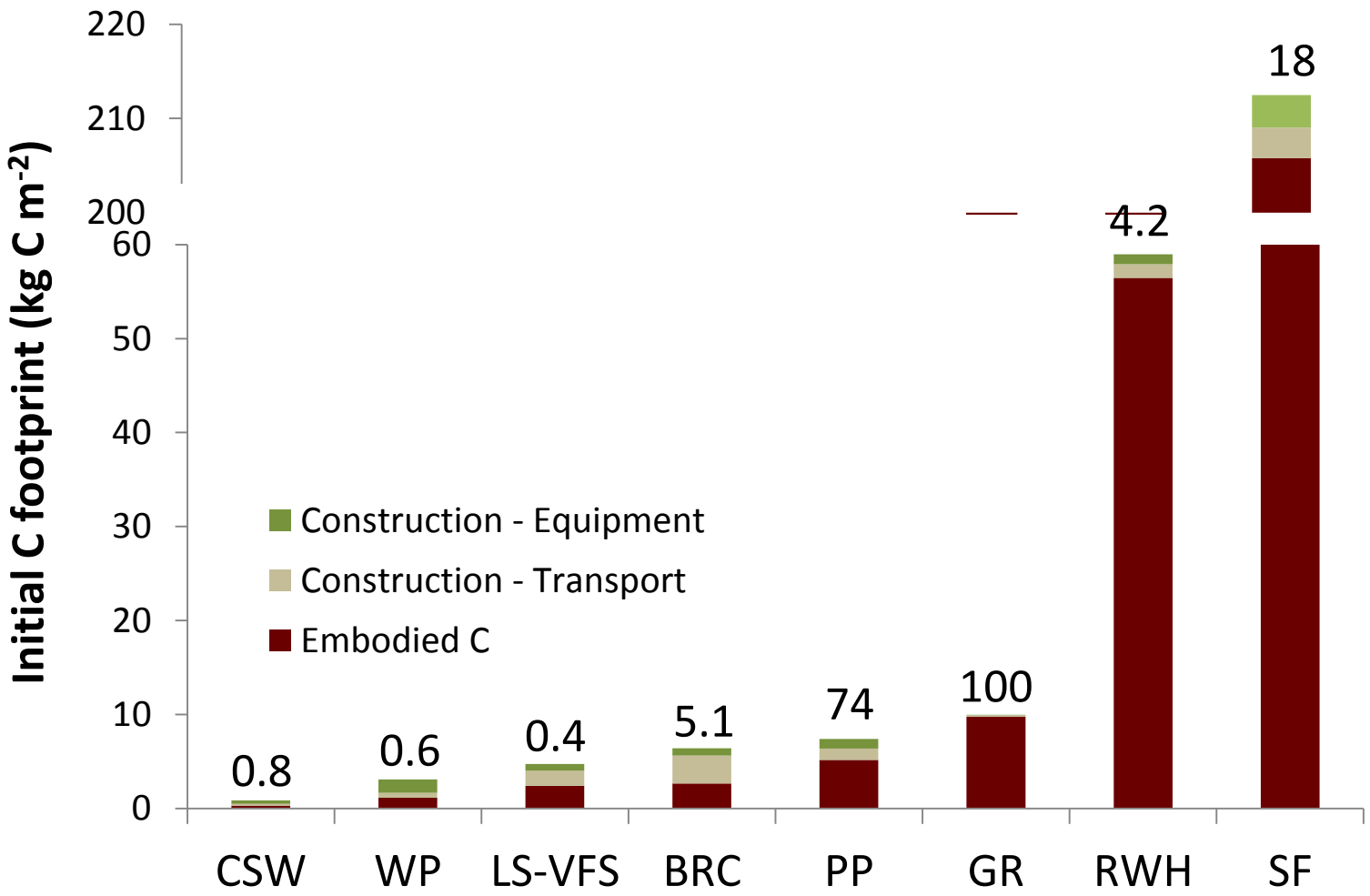
Concrete channel

Grassed swale

Conceptual model



Results – Embodied & Construction C



Moore & Hunt. Ecol. Eng. Sep 2013

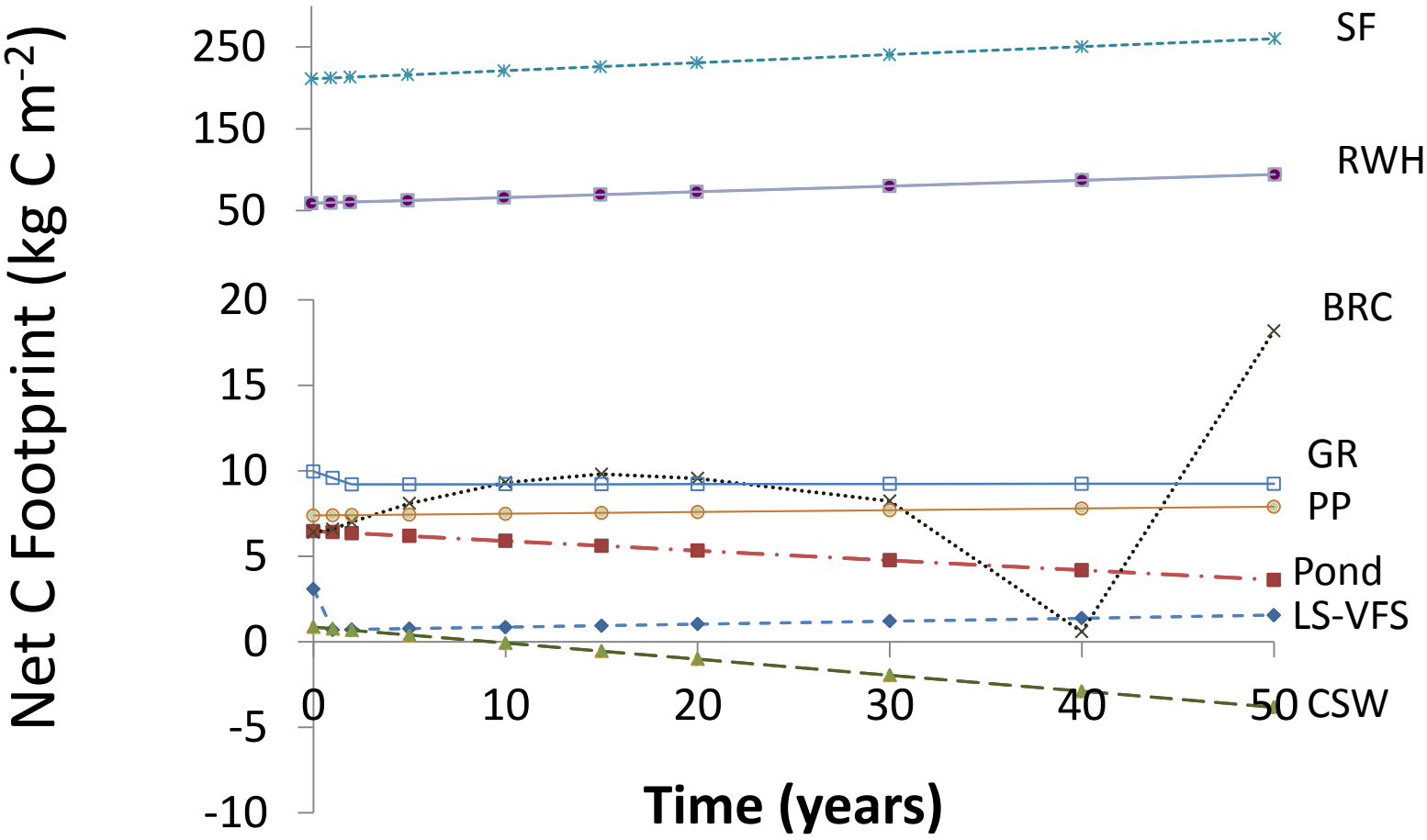
Results – Maintenance & Sequestration

SCM Type	Maintenance emissions (g C m^{-2} yr^{-1})	C sequestration (kg C m^{-2} yr^{-1})	Net (kg C m^{-2} yr^{-1})
Green roof	0.02	0.076[a]	0
Perm. Pavement	0.01	0	0.01
Sand filter	0.98	0	0.98
Bioretention cell	0.15	0.09[b]	0.06[b]
Rainwater harvesting	0.17	0	0.17
Wetland	0.07	0.12	-0.05
Level spreader – VFS	0.02	0.06	-0.04
Pond	0.28	0.1	0.18

[a]green roof sequestration rate sustained 2 years (Getter & Rowe, 2009)
[b]sequestration rate variable; 0.09 kg C m^{-2} yr^{-1} is average

Moore & Hunt. Ecol. Eng. Sep 2013

Results – Net footprint with time

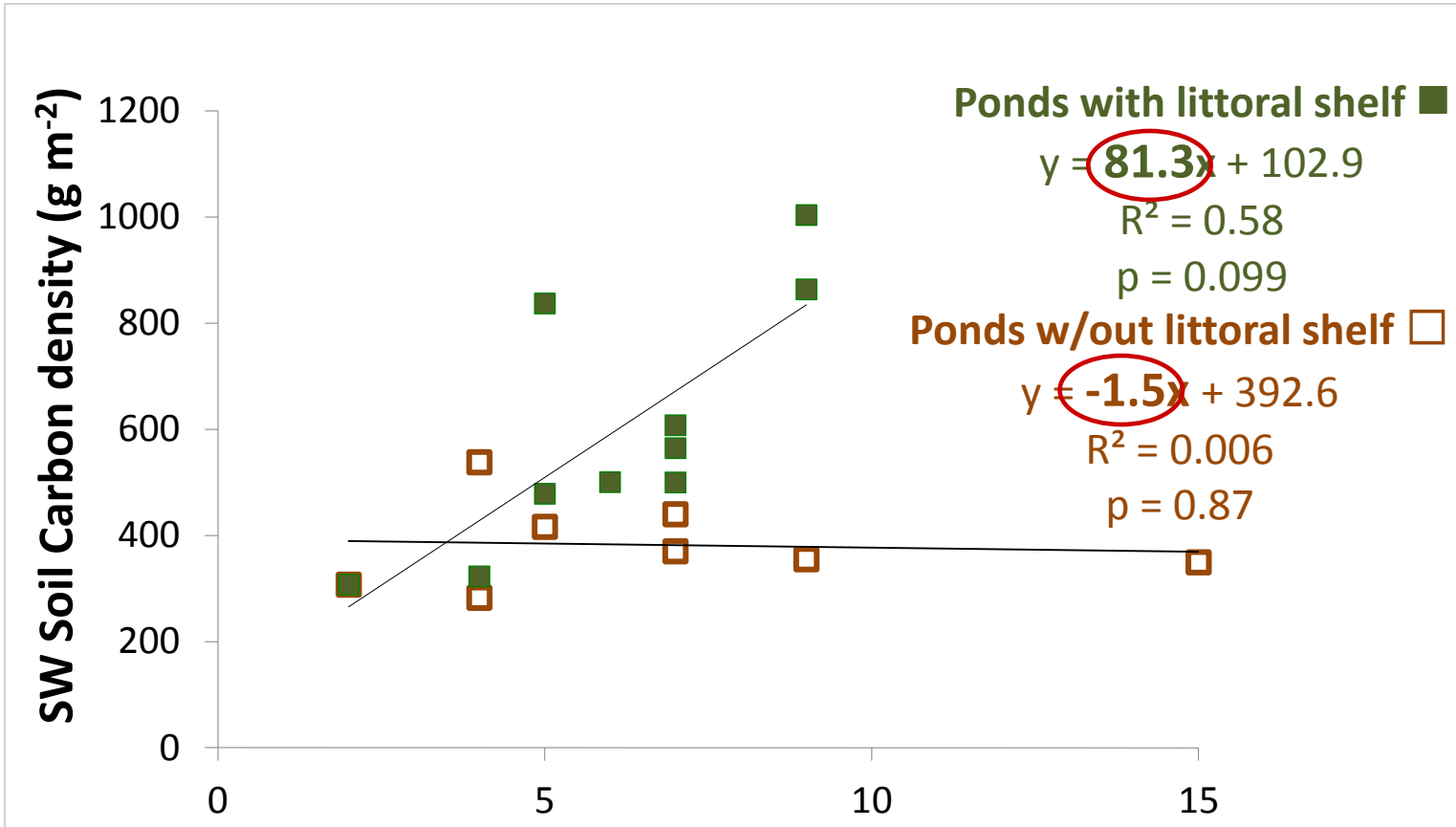


Moore & Hunt. Ecol. Eng. Sep 2013

Informing Designs of SCMs

2. Ecosystem service assessment: Ponds vs CSWs

Results – carbon sequestration



Soil carbon accumulation rates higher in ponds **with vegetated littoral shelves**

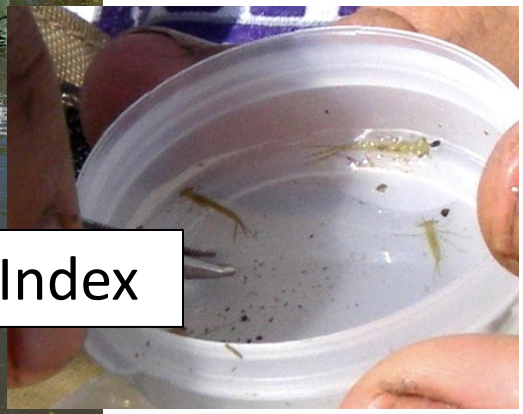
Moore & Hunt. Water Res. Dec 2012

Add aquatic shelves?

Other Ecosystem Services

- Biodiversity assessment

Vegetation surveys of OW, SW, and TI zones



Richness and Shannon Diversity Index

Aquatic macroinvertebrate sampling in SW zones

H_{03}: pond and CSW vegetation diversity is no different
H_{04}: pond and CSW macroinvertebrate diversity is no different

Ecosystem Service Assessment Methods

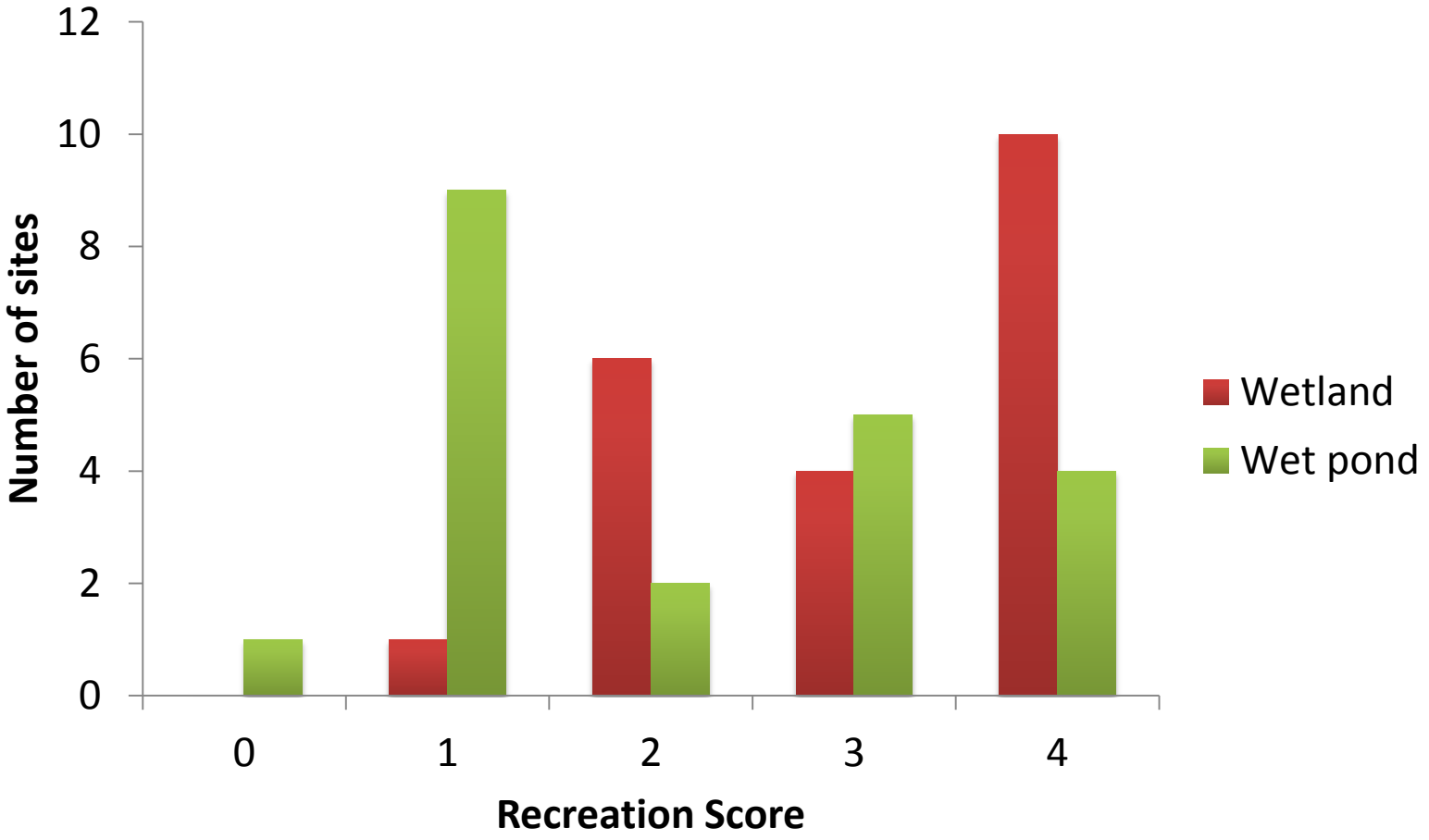
- Cultural services: do ponds and wetlands provide similar recreational and educational opportunities?

South Central LA Wetland Park

Watauga County (NC) Wetland

Sometimes we nail it with ponds!

Recreation survey: stormwater wetlands vs. ponds



Moore & Hunt. 2012. Wat Res.

Check out this Infiltration Basin

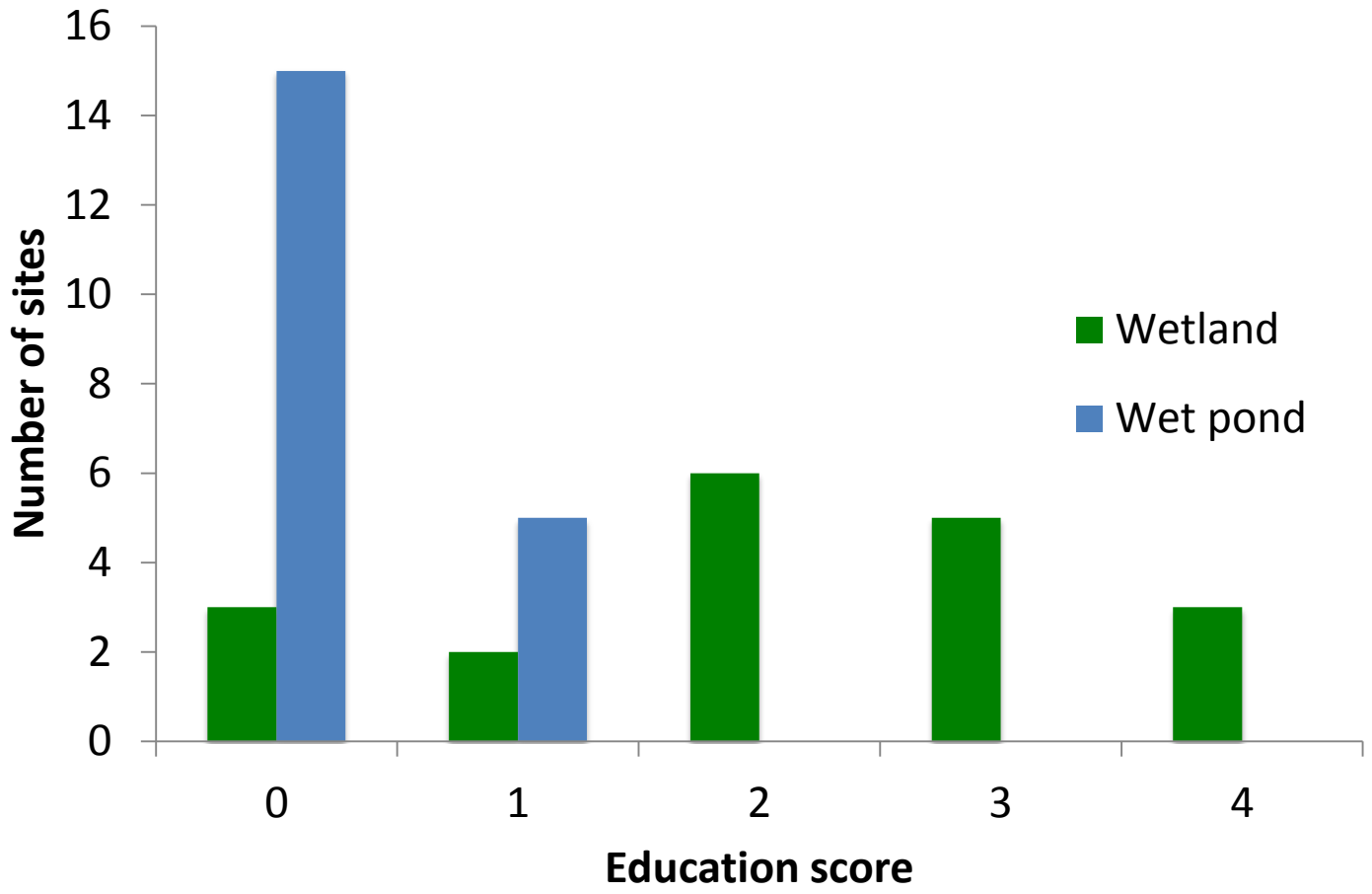
Vaxjo, SWE

Cultural services:

Education/scientific research

Smithfield-Selma Sr. High School Stormwater Wetland: Smithfield, NC
Photo courtesy of NCSU-BAE

Education survey: stormwater wetlands vs. ponds



Moore & Hunt. 2012. Wat Res.

Take Home Points

- The “Move” from LID to Green Infrastructure will…
  - Require holistic evaluation
- Valuation of non-traditional goals may become important
- Differences are observed among SCMs wrt Ecosystem Services delivered
- Valuation of Ecosystem Services will need to become necessary to “see this.”

Questions?